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Fugitive Hydrocarbon Emissions from Pacific Offshore Oil Platforms: Models, Emission Factors, and Platform Emissions

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In 1989, the U.S. Department of the Interior sponsored a field study that included the measurement of fugitive hydrocarbon emissions from seven offshore oil and gas production platforms located in outer continental shelf waters off the coast of Southern California. This study generated a set of emission factors for five different models for ten different combinations of component style and product stream as a function of a component's screening value measured one centimeter from the source with an organic vapor analyzer (OVA). These emission factors (ranging from 1 x 10^{-6} to 8.05 pounds of total hydrocarbon per day per component) are utilized together with an inventory of the components and the OVA screening value for each component to estimate total platform fugitive hydrocarbon emission rates. For the seven platforms included in this study, the total platform emission rates ranged from 42 to 140 pounds of hydrocarbon per day with more than 70 percent of the emissions due to a very small number of large emitters. The average platform non-methane emission rate was 20 pounds per day. A comparison with measurements made a decade ago indicates that technological advances and adoption of inspection and maintenance practices have reduced fugitive hydrocarbon emissions from these offshore facilities by more than 75 percent. Components in gas service were observed to have emission factors about an order of magnitude greater than the same components in liquid service due to the greater leak frequency of components in gas service.

Fugitive hydrocarbon emissions from offshore oil and gas production facilities may exacerbate air quality problems onshore. This first received attention in Southern California in the late 1950s. In 1979, EMSI, a division of Rockwell International, screened 173,609 components for leaks at 21 petroleum production and processing facilities, including eight offshore platforms, on behalf of the American Petroleum Institute (API).[1] This study generated fugitive hydrocarbon emission factors based on measurements of approximately 20 percent of the over 8,000 leaking components. The emission factors generated by this study did not receive wide acceptance because the emission factors for many of the component types were based on few measurements.

Implications

Fugitive hydrocarbon emissions from offshore oil production facilities are much lower than that estimated by regulatory agencies using outdated estimation techniques based on measurements made a decade ago. These findings which, based on recent studies, are also applicable to refineries and onshore oil production facilities, suggests that technological advances and improved inspection and maintenance practices have contributed significantly to controlling fugitive hydrocarbon emissions.

To address the issue of fugitive hydrocarbon emissions from platforms located in Pacific OCS waters, the Minerals Management Service (MMS) of the U.S. Department of the Interior sponsored a field study in 1989 that included emission rate measurements on seven platforms located off the Southern California coast. The facilities ranged in age from four to twenty-one years, and had ten to forty wells each with daily production rates of 29 to 23,000 barrels of oil and 1.4 million to 62.0 million cubic feet of gas.

The primary goal of this MMS-sponsored study was to determine fugitive hydrocarbon emission factors for components handling oil and gas on the seven Pacific OCS facilities, and to estimate the total fugitive hydrocarbon emission rate for each platform. First an inventory of all platform components was generated. Then leak tests of all accessible components were conducted and samples of fugitive hydrocarbon emissions from a representative number of accessible components were collected and subsequently analyzed for different chemical species. The results were used to develop emission factors for different component types and product streams. Finally, total platform emission rates were calculated using these emission factors.

Methodology

The study consisted of field operations, laboratory measurements, data management and analysis, and development of statistical models. Full details appear in the Final Report for this project.[2]

Field Operations

Initial Visit. An initial visit was made to each platform to establish communication between the sampling personnel and platform operators, and to become oriented with the facilities.

Inventorying Components. After delineation of the various processes on each platform, the accessible and inaccessible components that handled a minimum of 5 percent by weight organic material were inventoried separately. A component was considered to be accessible if it was no more than six feet above a catwalk. Since components in gas service have much higher leak rates as well as a higher occurrence of leakers than similar components in light or heavy liquid crude oil service, only two service designations were used: gas and liquid. A mixture of gas and liquid was classified as gas.

Table I. Total hydrocarbon emission factors for the four-range prediction model.

Component category[a]	Non-emitter (<500 ppm)	Low emitter (500-9999 ppm)	Medium emitter (10,000-100,000 ppm)	High emitter (>100,000 ppm)
	Emission Factor (pounds THC/day-component)			
CG	1.72E-03	3.21E-02	9.76E-02	1.32E+00
CL	9.66E-05	1.00E-02	9.73E-01	9.83E-01
D	1.47E-04	2.35E-01[b]	2.54E-01[c]	1.84E+00[c]
OG	7.82E-04	4.17E-02	1.71E-02	1.62E+00
OL	2.24E-03	3.41E-03	2.54E-01[c]	9.48E-01
PS	4.26E-04	4.51E-02[c]	2.54E-01[c]	1.73E+00[b]
VG	1.61E-03	1.44E-02	9.70E-02	1.49E+00
VL	7.38E-05	2.41E-02[b]	2.54E-01[c]	1.74E+00
XG	3.95E-04	1.15E-04[b]	8.80E-02	4.86E+00
XL	1.00E-06	4.51E-02[c]	2.54E-01[c]	1.84E+00[c]
GAS	1.35E-03	3.02E-02	8.86E-02	1.61E+00
LIQ	8.60E-04	8.66E-03	9.73E-01	1.20E+00
ALL	1.16E-03	2.75E-02	1.50E-01	1.56E+00

[a] Component categories: connection in gas or liquid service (CG, CL); diaphragm in gas service (D); open-ended valve in gas or liquid service (OG, OL); pump seal in liquid service (PS); valve in gas or liquid service (VG, VL); other component in gas or liquid service (XG, XL); component in gas service or liquid service (GAS, LIQ); average of all components (ALL).
[b] 1 data point.
[c] 0 data points.

Components were grouped into ten categories: valve in gas or liquid service (VG, VL), connection in gas or liquid service (CG, CL), open ended valve in gas or liquid service (OG, OL), pump seal in liquid service (PS), diaphragm in gas service (D), other components in gas or liquid service (XG, XL). Emissions from pressure relief valves and compressor seals on all seven platforms were vented to vapor recovery systems; thus, these components were not sources of fugitive emissions.

Screening Components for Leaks. All accessible components were checked for leaks with soap solution and/or a portable Foxboro Model 108 organic vapor analyzer (OVA). Components which indicated leaks by the presence of soap bubbles, and components which could not be tested directly with the soap solution (i.e., heated components, moving shafts and pistons) were screened with an OVA with the OVA probe inlet positioned 1 cm away from the surface of the component. The upper range of the OVA was extended to 100,000 ppm by using a 10:1 diluter. Calibration of the OVA was performed several times a day in the field with methane. All components that registered 500 ppm or above with the OVA were classified as "emitters." These components were tagged with a small metal tag and their OVA values were recorded. A subset of "non-emitters" were also tagged and their OVA values recorded. Platform operators were instructed not to repair tagged components unless they presented a safety hazard.

Emitter ranges were further defined by OVA readings as follows: (a) non-emitter: <500 ppm; (b) low emitter: 500 to 9,999 ppm; (c) medium emitter: 10,000 to 100,000 ppm; and (d) high emitter: >100,000 ppm.

Sampling. Half the 392 emitters and 0.1 percent of the non-emitters were sampled at random across all seven platforms based on the following criteria: (1) a total of 30 or 100 percent (whichever was less) of all emitters for each of the ten component categories; (2) 30 non-emitters in gas service and 30 non-emitters in liquid service; and (3) for the emitting connections and valves in gas service, the sampling frequency was increased in rough proportion to the total number of these components. Thirty samples for each component category are considered sufficient to estimate the emission factor within a factor of two of the mean value with a 95 percent confidence level.[3] Twenty-four samples were collected in duplicate to assess precision, and two background samples of ambient air were collected on each platform.

Sampling consisted of shrouding each component with polyethylene sheeting and collecting a sample from the shroud into a Tedlar bag using a battery-operated pump. For components with liquid leaks, a trap was incorporated to prevent liquids contaminating the sample pump. For those components with a liquid drip rate of at least 3 drips per minute, the estimated liquid drip rate was recorded. EPA assumes negligible emissions from components with less than 3 drips per minute.[4] The Tedlar bag samples were placed in a black plastic bag to prevent any photochemical reaction from occurring and then shipped to an onshore laboratory for analysis.

Laboratory Operations

Each sample was analyzed by gas chromatography for seven chemical species groups: methane, ethane, >C2 alkanes, ethylene, >C2 alkenes, benzene, and >C6 aromatics.

Data Management/Data Analysis

The data base was constructed as tables and indices using the Oracle™ Relational Data Base System on a micro VAX 3600 computer. The gas chromatography results (corrected for background and sampling flow rate) were used to derive the emission rate for each sampled component in units of pounds of total hydrocarbon per day.

Statistical Analyses: Models

The models fall into two broad groups: (a) component-oriented based on number of components for different component categories, and (b) production-oriented based on production rates. The models provide equations that predict the mean and upper and lower confidence bounds for the total platform emission rate as well as for the emission factors for different component categories.

Component-Oriented Models. These models include the one-range (simple average), leaker/non-leaker, emitter/non-emitter, four-range, and correlation models. In those instances where data did not exist for a given OVA range for certain component categories, the emission factors were calculated from the averages for other components.

The one-range model generates an average emission rate per installed component for each component category. Multiplying this average emission rate by the number of components for that category gives the emission rate for that component category. The total platform emission rate is then computed by totaling the emissions for each component category. The variance of the total platform emission rate is calculated from the sum of the variances of the individual component emission rates. Upper and lower confidence bounds for the total platform emission rate are computed from the total platform emission rate and its variance.

The four-range model generates four emission rate averages for each component category, one for each of the four OVA screening ranges. The end user of this emission estimation model needs to know the number of components in each OVA range for each component category and the emission factors by OVA range for each component category to estimate the total platform emission rate.

The leaker/non-leaker model and the emitter/non-emitter model generate two averages for each component category: ≥10,000 ppm and 0 to 9999 ppm, and ≥500 ppm and 0 to 499 ppm, respectively. The end user of these models needs to know the number of components in each OVA range for each component category.

The correlation model uses a non-linear power curve to fit the measured emission factors to OVA values. To apply the correlation equation, one must know the OVA reading for each component. For components where the OVA value is off-scale (i.e., >100,000 ppm), the emission factor and variance for high emitters from the four-range model is used.

The component-oriented models use the following equations to predict the mean and upper and lower confidence bounds of the total platform emission rate:

$$T = \Sigma_{c,r}(N_{c,r} * A_{c,r}) \quad (1)$$

$$V_T = \Sigma_{c,r}(N_{c,r}*V_{c,r} + N^2_{c,r}*V_{A_{c,r}} + A^2_{c,r}*V_{N_{c,r}}) \quad (2)$$

$$UCB = T + (C * V_T^{1/2}) \quad (3)$$

$$LCB = T - (C * V_T^{1/2}) \quad (4)$$

where T is the predicted emission rate for a platform and V_T is its variance; UCB and LCB are the upper and lower confidence bounds on T; $N_{c,r}$ is the number of components found in OVA range r for category c on the platform; $A_{c,r}$ is the emission factor and $V_{c,r}$ is its variance for components in category c and OVA range r; $V_{A_{c,r}}$ expresses the variance in $A_{c,r}$ and $V_{N_{c,r}}$ expresses the variance of $N_{c,r}$; and C is the critical value from the normal distribution (e.g., 1.645 at 90 percent confidence).

Production-Oriented Model. This model treats each platform as a unit rather than considering individual components. The total platform emission rate is estimated from the production rate of oil and gas.

Results and Discussion

Field Results

Component Inventory. Of the almost 112,500 components on the seven platforms, 80 percent were accessible. Connections in gas and in liquid service accounted for 52 and 32 percent, respectively, of the total number of components; valves in gas and in liquid service accounted for another 6 and 5 percent, respectively. Each of the other component categories accounted individually for less than 1 percent.

Screening Data. The OVA screening results indicated that components in gas service have a much higher chance of being an emitter compared to components in liquid service: 0.67 percent versus 0.09 percent. Open-ended valves in gas and liquid service, pump seals, and valves in gas service were more likely to leak than other component categories with 3.3 percent, 1.8 percent, 2.8 percent and 1.7 percent emitters, respectively.

Sampling Data. The sampling objectives were accomplished for every component category except open-ended valves. For this category 82 percent of the emitters were sampled instead of the planned 100 percent due to the much lower distribution of emitters on the last four platforms compared to the first three platforms. In addition to the emitters, 51 non-emitters in gas service and 33 non-emitters in liquid service were sampled.

Laboratory Results

Sample Composition. The average composition of the fugitive hydrocarbon emissions was 64 percent methane, 4 percent ethane, 29 percent higher alkanes, less than 1 percent aromatics, and no alkenes.

Emission Rates. The emission rates for the individual components, corrected for background hydrocarbon concentrations in ambient air, ranged from not detectable to 8.05 pounds of total hydrocarbon per day per component.

Model Results

Although only accessible components were sampled, emission rates for inaccessible components were included in the predictions of total platform emissions. Inaccessible components were assumed to have the same emission factors per component as accessible components based on the similarity of screening results for both accessible and inaccessible components on one platform. Deviations from this assumption are discussed in the following.

Emission Factors. Emission factors for the four-range model, by category and OVA range, are presented in Table I; emission factors for the other models are presented in Table II. The emission factors independent of category are shown with the category designation of "ALL"; components in gas service are

Table II. Total hydrocarbon emission factors for the emitter/non-emitter model, the leaker/non-leaker model, and the one-range model.

Component Category	Emission Factor (pounds THC/day - component) Non-emitter	Emitter	Non-leaker	Leaker	One-range
CG	1.72E-03	6.59E-01	1.77E-03	9.70E-01	5.20E-03
CL	9.66E-05	6.27E-01	9.80E-05	9.80E-01	3.22E-04
D	1.47E-04	2.35E-01	3.28E-03	1.46E+00	3.28E-03
OG	7.82E-04	5.97E-01	1.45E-03	1.12E+00	2.06E-02
OL	2.24E-03	2.96E-01	2.26E-03	8.33E-01	7.64E-03
PS	4.26E-04	8.86E-01	1.06E-03	1.73E+00	2.50E-02
VG	1.61E-03	7.02E-01	1.68E-03	1.07E+00	1.32E-02
VL	7.38E-05	1.17E+00	7.86E-05	1.74E+00	7.70E-04
XG	3.95E-04	2.45E+00	3.95E-04	3.49E+00	2.22E-02
XL	1.00E-06	9.28E-01	1.00E-06	1.46E+00	1.00E-06
GAS	1.35E-03	7.67E-01	1.42E-03	1.16E+00	6.85E-03
LIQ	8.60E-04	5.66E-01	8.64E-04	1.16E+00	1.36E-03
ALL	1.16E-03	7.49E-01	1.20E-03	1.16E+00	4.58E-03

Emitter defined as OVA value ≥500 ppm measured 1 cm from source; leaker defined as OVA value ≥10,000 ppm measured 1 cm from source.

Table III. Predictions of platform emission rates (pounds THC/day) based on the four-range model.

Platform Number	Total Components	Platform Rate	STD_DEV	LCB	UCB
1	16966	41.9	11.4	23.1	60.7
2	17905	62.2	14.5	38.3	86.1
3	24721	139.6	25.7	97.3	181.8
4	11932	41.8	10.6	24.4	59.3
5	11217	42.1	11.1	23.9	60.3
6	16065	99.4	19.2	67.8	131.0
7	13647	58.7	14.9	34.2	83.3

designated as "GAS"; and components in liquid service as "LIQ." As one can see, components in gas service have much higher emission factors than their counterparts in liquid service. The emission factor for "other" components in liquid service (XL) for the non-emitter range, after correcting for background, is indistinguishable from the detection limit of 1 x 10^{-6} pounds per day.

A correlation model relating emission factors to OVA values of 100,000 ppm and below (i.e., on-scale OVA readings only) was constructed to be category-free to eliminate the problem of very few data points for some component categories. The correlation between emission factors (in units of pounds per day per component) and OVA values for components in gas service fit the equation:

$$\text{Emission factor} = 1.43\text{x}10^{-5}(\text{OVA})^{0.869};\ \text{with } R^2 = 0.8196 \quad (5)$$

The correlation equation relating emission factors to OVA values for components in liquid service was:

$$\text{Emission factor} = 1.42\text{x}10^{-5}(\text{OVA})^{0.823};\ \text{with } R^2 = 0.8744 \quad (6)$$

The emission factors for components with OVA values greater than 100,000 ppm were assigned the same emission factor as the category-free, four-range model, namely 1.56 pounds per day for each component. For components in gas service with OVA values greater than 100,000 ppm, the average emission factor was 1.60 pounds per day versus 1.13 pounds per day for components in liquid service.

Component-Oriented Model Platform Emission Rates. The four-range model yields the most accurate estimates of total platform emission rates of all the models developed for this study since it requires the greatest resolution of components into categories and emission ranges. Predicted platform emission rates for the seven platforms based on the four-range model emission factors are presented in Table III. Platform emission rates are given in pounds of total hydrocarbon per day per platform. The "STD_DEV" (standard deviation) is the square root of the variance of the total platform emission rate. The "LCB" and "UCB" are the lower and upper confidence bounds at the 90 percent confidence level for the total platform emission rate. The total platform fugitive hydrocarbon emission rates for the seven platforms ranged from 42 to 140 pounds of hydrocarbon per day with more than 70 percent of the total platform emissions due to the very small number of components in the high emitter range.

Using a simpler category-free model, where categories are eliminated and only the dependence of component emission factors on OVA range is considered, was almost as effective in estimating total platform emission rates and confidence bounds as the full four-range model. The predicted platform emission rates for the leaker/non-leaker and emitter/non-emitter models were quite close to those of the four-range model. However, the standard deviations were somewhat higher for these two-range models, indicating added inaccuracy originating from the loss of detailed OVA information. The predicted platform emission rates for the seven platforms based on the category-free, one-range (simple average) model ranged from 51 to 113 pounds of hydrocarbon per day. As one would expect, the uncertainty in platform emission rates using this model is larger than that of the category-free, four-range model; the standard deviations were about double that of the four-range model.

Eight components on the seven platforms leaked liquid at a rate of at least 3 drips per minute. One pump seal that was repaired within several hours of discovery was leaking at 200 to 300 drips per minute. If 50 percent of the liquid leaking from all eight components volatilized, there would have been an additional 46 pounds of hydrocarbon emissions per day, or about 6.6 pounds per day per platform. This is an upper limit since many of the very large liquid leakers are repaired soon after the leak occurs.

Production-Oriented Model Platform Emission Rates. A regression between platform emission rates and current production rates generated the following equation:

$$\text{Platform rate} = 24.3 + 0.677(\text{CGP}) + 0.0025(\text{COP}) \quad (7)$$

where platform rate is in units of pounds per day; CGP is the current gas production rate in units of millions of cubic feet per day; and COP is the current oil production rate in units of barrels per day.

A similar regression based on peak production rates generated the following equation:

$$\text{Platform rate} = 10.1 + 0.376(\text{PGP}) + 0.0023(\text{POP}) \quad (8)$$

where PGP and POP are the peak gas and oil production rates, respectively.

Compared to the simple average model that assumes an emission rate equal to the average of the seven platform emission rates (69.4 pounds per day), a regression model relating total platform emission rates to oil and gas production rates was more precise. Specifically, the error using this regression model was reduced to 65 percent of the error using the simple average value.

Chemically-Speciated Emission Rates. The non-methane hydrocarbon and non-methane/non-ethane hydrocarbon platform emission rates were 28.5 and 22.3 percent, respectively, of the total hydrocarbon platform emission rates listed in Table III. The average non-methane emission rate was estimated to be 20 pounds per day per platform compared to an average of 15.5 pounds per day per platform for the non-methane/non-ethane emission rate.

Evaluation of Inspection and Maintenance Programs

A survey of the I & M programs in place at each platform was conducted to elicit information on leak detection methods, inspection frequency, the number and type of components included in the inspection, the date of the most recent inspection, and the maintenance methods. All platforms had some form of I & M program with inspections on platform 4 consisting solely of daily physical inspections of any component suspected of a leak (i.e., presence of drips or an odor). All other platforms used either soap solution or an OVA to screen components for leaks. The I & M programs on platforms 3, 5, and 6 consisted of inspecting only a subset of the larger accessible components, whereas a broad range of components, including relatively small pipe sizes were included on platforms 1, 2, and 7.

The inspection frequency for accessible components ranged from monthly (platforms 5 and 6) to quarterly (platform 7) to annually (platforms 1, 2, and 3). Inaccessible components (difficult or unsafe to screen components) were inspected annually on only two platforms (1 and 7). For two platforms (5 and 6), inaccessible valves larger than 2 inch pipe size were inspected monthly.

Based on the results of the survey, the I & M programs for platforms 1, 2, and 7 are considered comprehensive since they included the majority of all components. The I & M programs on platforms 3, 5, and 6 are considered limited in scope because they included only the larger components. Platform 4 was considered to have no formal I & M program since neither soap solution nor an OVA was used to identify leaking components.

Effect of I & M Programs on Platform Emissions. Table IV summarizes the four-range model predicted total platform emission rates and the average emission rate per component, as well as the leaker frequency and the emitter frequency for the seven platforms. No statistically significant differences were found for platforms with varying degrees of I & M. It is hypothesized that a combination of factors such as platform age and production rates in addition to differences in I & M programs influenced emissions. It appears that daily physical inspections alone on platform 4 were sufficient to control emissions on this platform comparable to that of a platform with a comprehensive I & M program.

Table IV. Fugitive hydrocarbon emission rates as a function of I & M program.

I & M Program	Platform Number	Platform Emission Rate (pounds THC/day)	Rate per Component (pounds THC/day)	Leaker Frequency[a]	Emitter Frequency[b]
Comprehensive	1	41.9	0.00247	0.0013	0.0024
Comprehensive	2	62.2	0.00347	0.0021	0.0033
Comprehensive	7	58.7	0.00430	0.0030	0.0053
	Average	54.3	0.00341	0.0021	0.0037
Limited	3	139.6	0.00565	0.0045	0.0067
Limited	5	42.1	0.00375	0.0027	0.0033
Limited	6	99.4	0.00619	0.0040	0.0066
	Average	93.7	0.00520	0.0037	0.0055
No formal	4	41.8	0.00351	0.0023	0.0036

[a] Fraction of components with OVA values ≥10,000 ppm, measured 1 cm from source.
[b] Fraction of components with OVA values ≥500 ppm, measured 1 cm from source.

Emissions from Inaccessible Components

As of 1992, regulatory agencies in Southern California require that accessible components be inspected quarterly and inaccessible components and components unsafe to monitor be inspected annually. To the extent that these guidelines are followed today, all seven platforms involved in the study would be considered to have controlled emissions. However, the I & M survey indicated that the Pacific OCS operations had a variety of I & M programs in 1989. Consequently, part of the component population was subject to I & M programs very similar to those required by the local regulatory agencies, and part of the component population could be relatively uncontrolled.

To estimate emissions from inaccessible components one can either adopt the emission factors developed in the current study for accessible components, with the assumption that inaccessible components have the same leak frequency as accessible components. Or, based on the Santa Barbara County APCD's claim that there is a factor of five difference in emission rates between uncontrolled emissions and controlled emissions,[5] one can set the emission factors for inaccessible components equal to five times that of accessible components on a per component basis. These two estimates should cover the range of actual values for inaccessible components.

Comparison with Other Studies

Fugitive hydrocarbon emission factors for components in use at oil and gas production facilities are published in EPA Document AP-42.[6] These factors were developed over ten years ago in studies involving components at refineries and do not reflect current technology. For example, a recent study sponsored by API found that the emission rates from valves at refineries, that are subject to a quarterly I & M program, were approximately three percent of the AP-42 predicted values.[7]

The emission factors measured in the current MMS study were compared with that obtained from two Pacific OCS facilities included in the earlier API/Rockwell study.[1] These results, presented in Table V, indicate that advances in technology and the adoption of I & M programs over the past decade have caused the average emission factor for components on Pacific offshore facilities to decrease by a factor of 3.5. According to the API/Rockwell study, 87 percent of the total facility emissions were due to just 0.5 percent of the components with leaks greater than 1 liter per minute. Thus, controlling the emissions from just this small percentage of high leaking components would have reduced total platform emissions significantly. Recent I & M records for four platforms located in state waters off the coast of Santa Barbara, California indicate a 50 percent reduction in the number of moderate size leaks (>10,000 ppm) within a year of adopting a quarterly I & M program.[5]

Table V. Emission factors for Pacific OCS oil and gas facilities.

Component Category	Emission Factors (pounds THC/day — component) API Study	MMS Study
CG	0.015	0.0052
CL	0.0027	0.00032
D	0.005	0.0033
OG	0.063	0.021
OL	0.0004	0.0076
PS	0.020	0.025
VG	0.065	0.013
VL	0.002	0.00077
XG	0.074	0.022
XL	0.005	0.000
Average	0.0157	0.0046

Results from this study should not be applied universally to all offshore oil and gas production facilities. The results from the earlier API/Rockwell study indicated that offshore facilities located in the Gulf of Mexico had more than a factor of two higher emissions per component compared to facilities located in Pacific OCS waters: 0.036 versus 0.016 pounds THC/day per component.

Conclusion

Pacific OCS platforms include thousands of components which are potential sources of fugitive hydrocarbon emissions. However, only 0.67 percent of the components in gas service and 0.09 percent of the components in liquid service were found to be emitters. The reasons for this low number of leaking components compared to results from past studies include the use today of improved seals and packings in components, the use of more welded connections, monthly inspections by MMS staff, built-in sensors for methane and H_2S, and the use of vapor recovery systems to capture emissions from pressure relief valves and compressor seals. The categories with the highest frequency of emitters were open-ended valves in gas service and pump seals in liquid service, with 3.3 percent and 2.8 percent emitters, respectively.

On the average, fugitive hydrocarbon emissions from the Pacific OCS platforms were made up of 64 percent methane, 4 percent ethane, 29 percent higher alkanes, and less than 1 percent benzene and other aromatics.

Both component- and production-oriented models were developed to predict fugitive hydrocarbon emissions from Pacific OCS oil and gas production platforms. The component-oriented models require component inventories with or without screening measurements as inputs, and yield confidence bounds on their predictions. For typical platforms with screening data, the 90 percent confidence bounds are within 50 percent of the predicted emission rate. Production-oriented models are based on the knowledge of production rates or production capacities.

The average emission factor for accessible components on Pacific OCS platforms measured in the current study was 0.0046 pounds per day which is about 25 percent of that measured a decade ago due to advances in technology and implementation of I & M programs. The upper limit for the average emission factor for inaccessible components, which constitute less than 10 percent of the total platform component inventory, is five times this value.[5] Thus, the potentially higher emissions from uncontrolled inaccessible components could increase total platform emission rates by about 40 percent compared to an estimate that assumes that the emission factors for inaccessible and accessible components are the same.

The four-range prediction model estimated total hydrocarbon emissions of 40 to 140 pounds per day per platform for the seven Pacific OCS facilities. These values exclude emissions from liquid drips which if not repaired quickly could add an additional 7 pounds per day per platform. The reactive organic carbon emission rates are much lower with the average non-methane hydrocarbon emission rate equal to 20 pounds per day per platform. It should be pointed out that for facilities that do not capture the emissions from compressor seals and pressure relief valves by a vapor recovery system, the uncontrolled emissions from these component types are quite high: 0.3 pounds per day per component and 3.9 pounds per day per component, respectively.

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